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PROBABILITY OF INJURY FROM AIRBLAST DISPLACEMENT AS A FUNCTION OF YIELD AND RANGE

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Topical Report

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20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this study was to predict the probability of impact injuries due to whole-body translation by airblast as a function of yield and ground range. Predictions were made for personnel in different orientations in open terrain and near structural complexes.

A mathematical model was used to calculate the time-displacement history of personnel from considerations of aerodynamic →

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20. ABSTRACT (Continued)

drag and ground friction. Predicted values of maximum velocity, displacement at maximum velocity, and total displacement were tabulated for 1224 exposure conditions. These conditions included both air and surface bursts with yields from 1 T to 100 MT and peak overpressures from 2 to 97 psi.

Biological criteria were presented which indicate that personnel subjected to decelerative tumbling over open terrain can tolerate much higher velocities than personnel impacting a nonyielding, flat surface at normal incidence. These criteria were used in preparing range-yield plots for 1-, 2.5-, 5-, and 50-percent probabilities of serious injury to prone personnel in the vicinity of a surface burst.

Methods for extending the presented results to other exposure conditions were discussed.

PREFACE

This work unit, Decelerative Tumbling Blast Effects on Personnel. Contract No. DNA 001-74-C-0120, was part of the subtask, Biological Effects of Blast Environments.

This study was under the direction of R. K. Jones. The technical assistance of W. Hicks, K. Saunders, A. Shaw, and W. S. Jackson is acknowledged. T. Minagawa performed the technical photography and prepared the illustrative material. The report was typed and compiled by B. Martinez.

This research was conducted according to the principles enunciated in the "Guide for Laboratory Animal Facilities and Care," prepared by the National Academy of Sciences, National Research Council.

TABLE OF CONTENTS

	Page
PREFACE	1
INTRODUCTION	5
MATHEMATICAL MODEL	6
Ground Friction	6
Acceleration Coefficient	7
Blast-Wave Parameters	10
CALCULATED VELOCITIES AND DISPLACEMENTS	12
INJURY PROBABILITY VS RANGE AND YIELD	13
REFERENCES	20
APPENDIX	23
DISTRIBUTION	35

LIST OF ILLUSTRATIONS

Figure		Page
1	1- to 5-Percent Probability of Impact Injuries to Prone Personnel in Open Terrain	14
2	1- to 5-Percent Probability of Impact Injuries to Prone Personnel Near Structures	15
3	50-Percent Probability of Impact Injuries to Prone Personnel in Open Terrain	16
4	50-Percent Probability of Impact Injuries to Prone Personnel Near Structures	17
A-1	Velocity-Displacement History of Prone Personnel in a Random Orientation Exposed to an Overpressure Level of 27.4 psi from a 10-KT Surface Burst	24

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		Page
A-2	Maximum Translational Velocity of Prone Personnel End-On to the Wind	25
A-3	Maximum Translational Velocity of Prone Personnel in a Random Orientation	26
A-4	Maximum Translational Velocity of Prone Personnel Side-On to the Wind	27
A-5	Maximum Translational Velocity of Standing Personnel Front- or Back-On to the Wind	28

LIST OF TABLES

Table		Page
A-1	Blast-Wave Parameters Used to Calculate Displacement of Personnel	29
A-2	Displacement of Prone Personnel End-On to the Wind	30
A-3	Displacement of Prone Personnel in a Random Orientation	31
A-4	Displacement of Prone Personnel Side-On to the Wind	32
A-5	Displacement of Standing Personnel Front- or Back-On to the Wind	33
A-6	Biological Criteria	34

INTRODUCTION

One of the major hazards to personnel in the vicinity of an explosion is associated with whole-body displacement induced by blast winds. The purpose of this study was to predict the probability of impact injury from displacement as a function of yield and ground range. Predictions were made for personnel in different orientations in open terrain and near structural complexes. A mathematical model (Reference 1) was used to calculate the time-displacement history of personnel from considerations of aerodynamic drag and ground friction. The model had been verified previously using data from anthropomorphic dummies translated over open terrain by high-explosive (HE) and nuclear detonations (References 2 and 3).

Two types of terrain were of interest because of differences in the translational velocities required to produce injuries. In open terrain, personnel undergo decelerative tumbling, in which case the energy of motion is dissipated slowly through a series of glancing impacts, and relatively high velocities can be tolerated. In contrast, personnel translating near a structural complex may impact rigid structures at approximately normal incidence, and the energy of motion is dissipated much more rapidly with a corresponding

increase in the likelihood of injuries. The biological criteria used in the present study were derived from experiments (Reference 4) by airblast from a shocktube. Injuries commonly incurred during either type of deceleration included lacerations, contusions, fractures, dislocations, and damage to internal organs.

MATHEMATICAL MODEL

The mathematical model used to calculate blast-induced translation of personnel (Reference 1) was adapted to an electronic digital computer. The computer program is quite general in that it takes into account variable ground friction, aerodynamic-drag characteristics, and blast-wave parameters.

Ground Friction

The average deceleration, due primarily to frictional effects with the ground, of a 165-lb man undergoing decelerative tumbling has been estimated in Reference 1 to be approximately $8.9029\ V_i^{0.38308}$ ft/sec^2, where V_i is the instantaneous translational velocity in ft/sec. This

relationship was derived from translational data obtained with guinea pigs, rabbits, dogs, and a goat by scaling to an animal the size of man. Previous calculations have indicated that the ground-friction formula also applies reasonably well to full-scale anthropomorphic dummies (Reference 3).

Acceleration Coefficient

In order to calculate the aerodynamic drag forces on a man it is necessary to know, at each instant, the acceleration coefficient, α , defined as the projected area presented to the wind multiplied by the drag coefficient and divided by the body mass (Reference 5). The α varies as the orientation of a man changes during translation. A value of approximately 0.03 ft^2/lb has been estimated to be the average α for a random orientation (i.e., considering all possible orientations to be equally likely) of an unbent man.

The α for a prone man end-on to the wind is 0.0063 ft^2/lb (Reference 6). Data obtained on 500-ton HE tests (Reference 3) suggest that, for near-ideal conditions, asymetries will cause a dummy which was initially prone and end-on to the flow to turn side-on to the wind after about 13 ft of displacement. The details of the subsequent displacement were not obtained, but the assumption of a random orientation

seems reasonable. An emperical fit to the data yielded the following relationships:

$$\alpha = 0.0063 + (D_i/31)^4 \quad \text{for} \quad 0 \leq D_i < 12.2$$

$$\alpha = 0.03 \quad \text{for} \quad 12.2 \leq D_i$$

where α is expressed in ft^2/lb and D_i is the instantaneous displacement in feet.

The α for a prone man in a random orientation is 0.014 ft^2/lb (Reference 6). This value is smaller than the average α for a man considering all orientations because a prone man cannot be face- or back-on to the wind. The data mentioned in Reference 3 suggest that, on the average, a dummy which was initially prone in a random orientation will turn side-on to the wind after about 6 ft of displacement. The following relationships were used to approximate the acceleration coefficient during the displacement of a man initially prone in a random orientation:

$$\alpha = 0.014 + (D_i/47)^2 \quad \text{for} \quad 0 \leq D_i < 5.9$$

$$\alpha = 0.03 \quad \text{for} \quad 5.9 \leq D_i$$

The α for a prone man side-on to the blast is 0.022 ft^2/lb. The data indicate that dummies initially in this orientation will start to roll within a very short displacement

(~1 ft). The average α for a man rolling with his long axis perpendicular to the wind is 0.038. It is not known after what displacement the orientation would typically become more random in nature. Because of these uncertainties, an α of 0.03 ft^2/lb was assumed throughout the displacement of a man initially prone and side-on to the wind.

The only calculations made for a standing man were for the worst case, i.e., for a man initially face- or back-on to the wind. Data obtained with dummies indicate that these two initial orientations will result in approximately the same displacement (Reference 3). It should be noted that orientation probably influences the displacement of a standing man less than in the case of a prone man, inthat the α of a standing man can range from only 0.022 to 0.052, whereas the α of a prone man can range from 0.0063 to 0.022 depending on the orientation.

At overpressures below 2.7 psi, the standing dummies toppled over with their feet having undergone almost no displacement. At overpressures above 5.3 psi, the legs were blown out from under the dummies such that they became airborne almost immediately. Typically a standing dummy rotated such that it first impacted the ground on its head after a displacement of from 10 to 15 ft. Rather than attempting to

adapt the mathematical model to closely approximate the complexities introduced by the sometimes airborne displacements, a simpler approach was considered. Calculations were made assuming that the α remained constant at 0.052 and that the ground friction was operative throughout the displacement (Reference 3). The predictions agree well with experimental displacements obtained over a limited range of yield (50 T to 38 KT) and overpressure (5 to 50 psi). The good agreement is probably due in part to two compensating errors: (1) assuming the α remains constant at 0.052 should result in the predicted velocities being too high because the dummies rotated, thus reducing the α; (2) assuming the ground friction to always be operative should result in the predicted velocities being too low because the dummies were airborne during the first 10 ft of displacement.

Blast-Wave Parameters

The blast-wave parameters used to predict the displacement of personnel were derived primarily from data for nuclear detonations in References 7 and 8. Calculations were made at selected yields and ground ranges for surface bursts and for upper and lower optimum heights-of-burst (HOB's). The optimum HOB is defined as the one which tends to maximize, for a given ground range, both the peak dynamic pressure and the impulse of the positive dynamic pressure. Thus the optimum

HOB would also tend to maximize the translational velocity of personnel for a given ground range. The airblast data indicate that at intermediate ground ranges there are two local optimum HOB's, with the upper optimum HOB giving the larger dynamic-pressure levels and impulses for scaled ground ranges greater than approximately 770 $ft/(KT)^{1/3}$, and the lower optimum HOB giving the larger dynamic-pressure levels and impulses for smaller scaled ground ranges.

Table A-1 lists the pertinent blast-wave parameters. Note that values are given for both upper and lower optimum HOB's for scaled ground ranges between 400 and 950 $ft/(KT)^{1/3}$. For surface bursts the peak overpressures given in the table range from 2 to 97 psi corresponding to peak dynamic pressures between 0.093 and 140 psi.

Double-exponential equations, of the types used in Reference 8, were fitted to the overpressure and dynamic-pressure waves to facilitate their being entered into the computer program. The Rankine-Hugoniot relations were assumed to apply at the shock front, and changes within the shock wave were assumed to be adiabatic. It was thus possible to use the overpressure to calculate the air density, which in turn could be combined with the dynamic pressure to calculate the wind speed, all of these quantities varying with time.

In calculating a displacement, the blast-wave parameters were evaluated at fixed time intervals, the size of which depended on the yield of interest. For yields of 1 T, 1 KT, 1 MT, and 100 MT the time intervals were 5 μsec, 50 μsec, 0.5 msec, and 2 msec, respectively. These values also represent the time-step sizes used in solving the differential equations of motion by Runge-Kutta methods.

CALCULATED VELOCITIES AND DISPLACEMENTS

Each of the 34 runs listed in Table A-1 was analyzed in connection with nine yields (ranging from 1 T to 100 MT by factors of 10) and four initial orientations (three prone and one standing). Thus a total of 1224 displacements were predicted using the computer. Figure A-1 shows a typical velocity-displacement history for a prone man in a random orientation exposed to an overpressure level of 27.4 psi from a 10-KT surface burst. As was the usual case, the maximum velocity, V, was achieved within a displacement, S, which was short compared to the total displacement, D. Likewise, the time to peak velocity was short compared to the total time of displacement.

The predicted V, S, and D values for all of the computer runs are listed in Tables A-2 through A-5. For a given

yield and initial orientation, the V and D values always increased with the peak overpressure. The S values also increased with the peak overpressure except for some slight reversals at the higher overpressures. These reversals may be an anomaly caused by the finite size of the time step used in the calculations. Even if this is the case, the effect on the computed V and D values would be minimal. The predicted maximum velocities in Tables A-2 through A-5 for personnel exposed to a surface burst have been plotted in Figures A-2 through A-5.

INJURY PROBABILITY VS RANGE AND YIELD

Table A-6 indicates the probability of serious injury (fracture or ruptured internal organ) as a function of velocity for personnel undergoing either decelerative tumbling or impact at normal incidence against a nonyielding, flat surface. The velocities are in agreement with estimates of man's tolerance to impact in Reference 9.

Figures A-2 through A-4 were used to determine the scaled ground ranges corresponding to the velocities in Table A-6. Ground range vs nuclear yield was plotted in Figures 1 and 2 for 1-, 2.5-, and 5-percent probabilities of injury to prone personnel and in Figures 3 and 4 for 50-percent

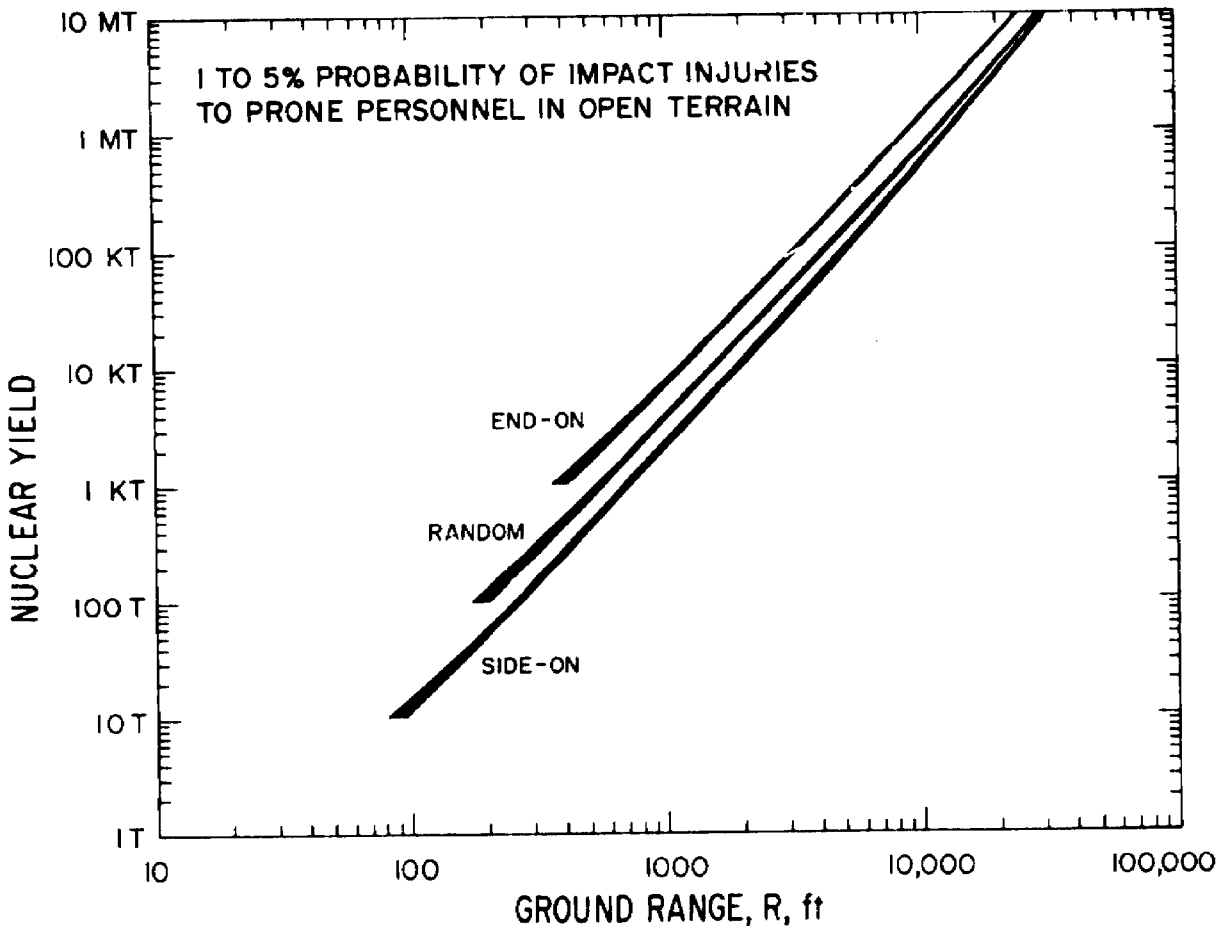

Figure 1. 1- to 5-Percent Probability of Impact Injuries to Prone Personnel in Open Terrain. The right-hand edge, center, and left-hand edge of each curve correspond to probabilities of 1, 2.5, and 5 percent, respectively. Computed for a surface burst.

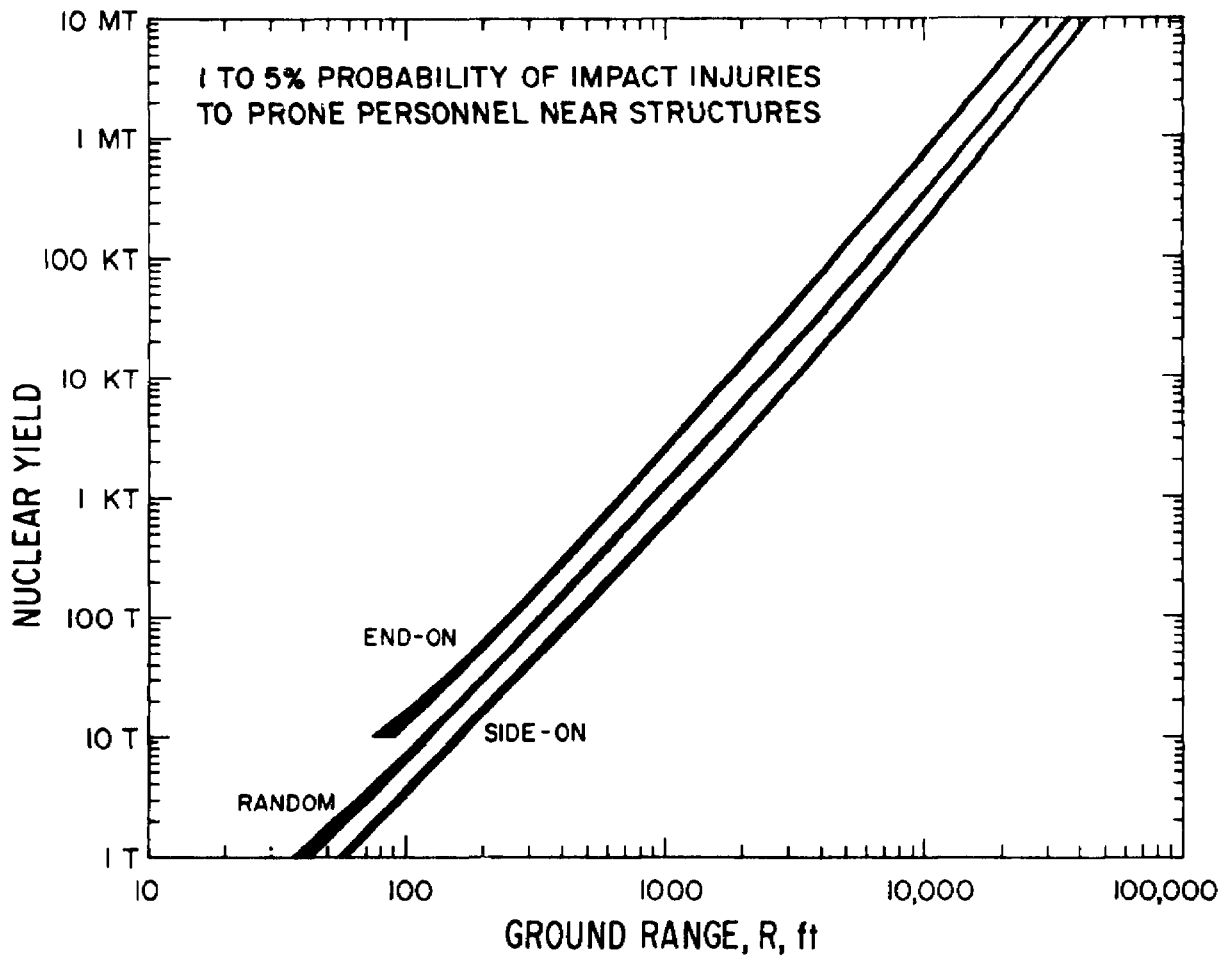

Figure 2. 1- to 5-Percent Probability of Impact Injuries to Prone Personnel Near Structures. The right-hand edge, center, and left-hand edge of each curve correspond to probabilities of 1, 2.5, and 5 percent, respectively. Computed for a surface burst.

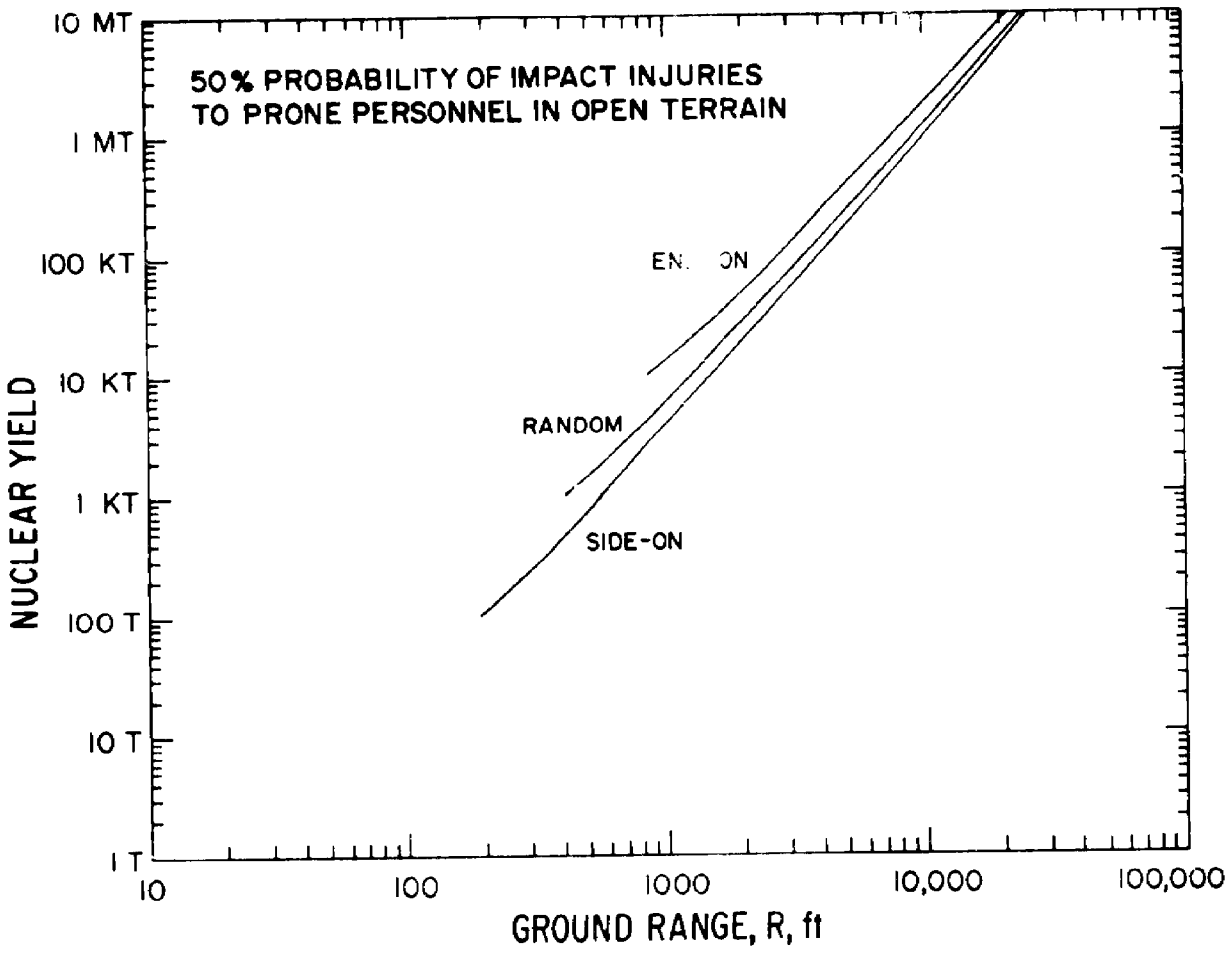

Figure 3. 50-Percent Probability of Impact Injuries to Prone Personnel in Open Terrain. Computed for a surface burst.

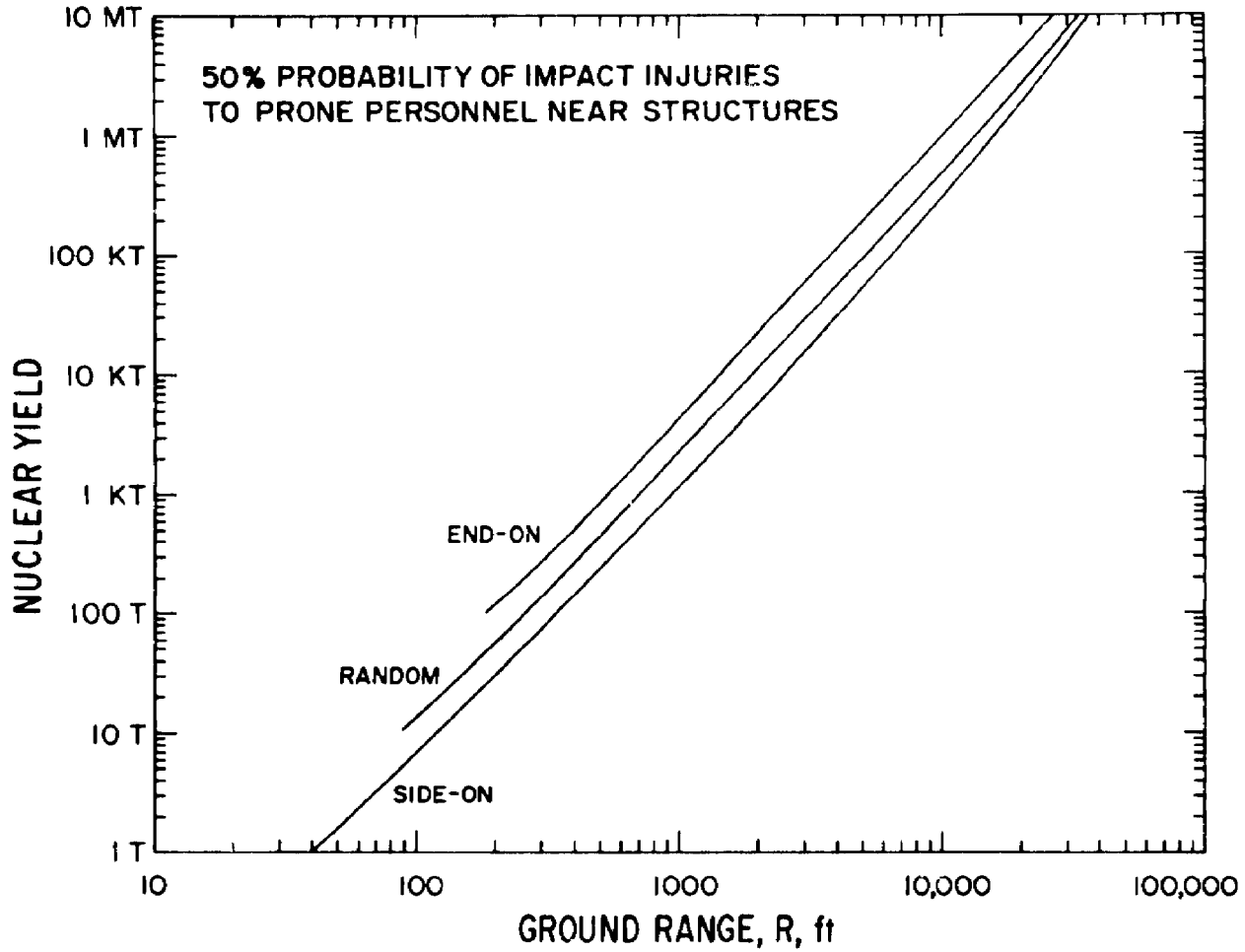

Figure 4. 50-Percent Probability of Impact Injuries to Prone Personnel Near Structures. Computed for a surface burst.

probabilitiy of injury. Implicit in Figures 2 and 4 is the assumption that personnel near structures impacted, at normal incidence, a nonyielding, flat surface at the instant of maximum velocity.

Some of the curves in Figures 1 through 4 do not extend to 1 T because no attempt was made to extrapolate to yields less than those that could be read directly from the curves in Figures A-2 through A-4. However, the missing portions of the curves correspond to peak overpressures of greater than 55 psi, such that the primary-blast hazard would probably override the displacement hazard.

From Figures 1 through 4 it can be seen that, for a given injury probability and yield, the ground range is very dependent on both initial orientation and type of terrain. For example, for a 50-percent probability of injury from a 10-KT surface burst, the ground ranges for end-on and side-on prone personnel are approximately 850 and 1500 ft in open terrain and 1400 and 2500 ft near structures. In contrast, varying the injury probability from 1 to 5 percent has a relatively small influence on ground range. For example, for a 10-KT surface burst in open terrain, the ground ranges for 1- and 5-percent probabilities of injury are approximately 1200 and 1100 ft for end-on prone personnel and 2000 and 1900 ft for side-on prone personnel.

Four methods of extending the possible applications of the predictions presented in this paper are worth noting:

First, velocities read from Table A-5 or Figure A-5 could be used to estimate injury probability vs range and yield for standing personnel.

Second, it would be possible to predict the approximate displacement of personnel subjected to a near-classical dynamic-pressure wave generated by an unspecified source by assuming that (for a given orientation) V, S, and D are each a function of only the peak dynamic pressure and the impulse of the positive dynamic pressure. Further, as the duration of the wave decreases, the significance of the wave shape and peak dynamic pressure decreases, such that V and D become functions of only the impulse of the positive dynamic pressure, and S approaches zero. All of these functions could be derived from the data in Tables A-1 through A-5.

Third, for a HOB lower than those listed in Table A-1, it is reasonable to use logarithmic interpolation to estimate translational velocities and displacements. For example, for a HOB of 200 ft/$(KT)^{1/3}$, one could interpolate between values for a surface burst and a

lower optimum HOB for ground ranges between 400 and 950 ft/$(KT)^{1/3}$, and interpolate between values for a surface burst and an upper optimum HOB for ground ranges between 1100 and 2600 ft/$(KT)^{1/3}$.

Finally, the predictions may be applied directly to an HE detonation by considering a nuclear yield twice as large as the HE yield. Thus, for 500 tons of high explosives, one would read 1 KT on the nuclear yield scales in the figures. This procedure is based on the assumption that approximately one-half of the energy released in a nuclear detonation goes into airblast.

REFERENCES

1. Fletcher, E. R. and I. G. Bowen, "Blast-Induced Translational Effects," Technical Progress Report, DASA-1859, Defense Atomic Support Agency, Department of Defense, Washington, D. C., November 1966. Subsequently published in Ann. N. Y. Acad. Sci. 152: 378-403 (October 28) 1968.

2. Taborelli, R. V., I. G. Bowen, and E. R. Fletcher, "Tertiary Effects of Blast--Displacement," USAEC Civil Effects Test Group Report, WT-1469, Office of

Technical Services, Department of Commerce, Washington, D. C., May 22, 1959.

3. Fletcher, E. R., D. R. Richmond and R. K. Jones, "Project LN402--Blast Displacement of Dummies in Open Terrain and in Field Fortifications," in Event Diel Pack Symposium Report, March 30-April 2, 1971, Vol. II, pp. 607-626, The Technical Cooperation Program, The Defence Research Board of Canada, Ottawa, Ontario, Canada, March 1971.

4. Richmond, D. R., E. R. Fletcher, R. K. Jones and W. S. Jackson, "Airblast Effects Inside Field Fortifications," Final Project Officer's Report, Mixed Company Event, Project LN401, POR 6622-1, Defense Nuclear Agency, Washington, D. C., 18 June 1974.

5. Fletcher, E. R., R. W. Albright, V. C. Goldizen and I. G. Bowen, "Determinations of Aerodynamic-Drag Parameters of Small Irregular Objects by Means of Drop Tests," USAEC Civil Effects Test Operations Report, CEX-59.14, Office of Technical Services, Department of Commerce, Washington, D. C., October 1961.

6. Schmitt, T. J., "Wind-Tunnel Investigation of Air Loads on Human Beings," Report 892 (Aero 858), The

Department of the Navy, The David W. Taylor Model Basin Aerodynamics Laboratory, Washington, D. C., January 1954.

7. Dolan, P. J. (Editor), The Effects of Nuclear Weapons, rev. ed. 1975, Energy Research and Development Agency (formerly U. S. Atomic Energy Commission), Washington, D. C., (in draft).

8. Brode, H. L., "A Review of Nuclear Explosion Phenomena Pertinent to Protective Construction," R-425-PR, The Rand Corporation, Santa Monica, California, May 1964.

9. Hirsch, A. E., "The Tolerance of Man to Impact," Ann. N. Y. Acad. Sci. 152: 168-171, (October 28) 1968.

APPENDIX

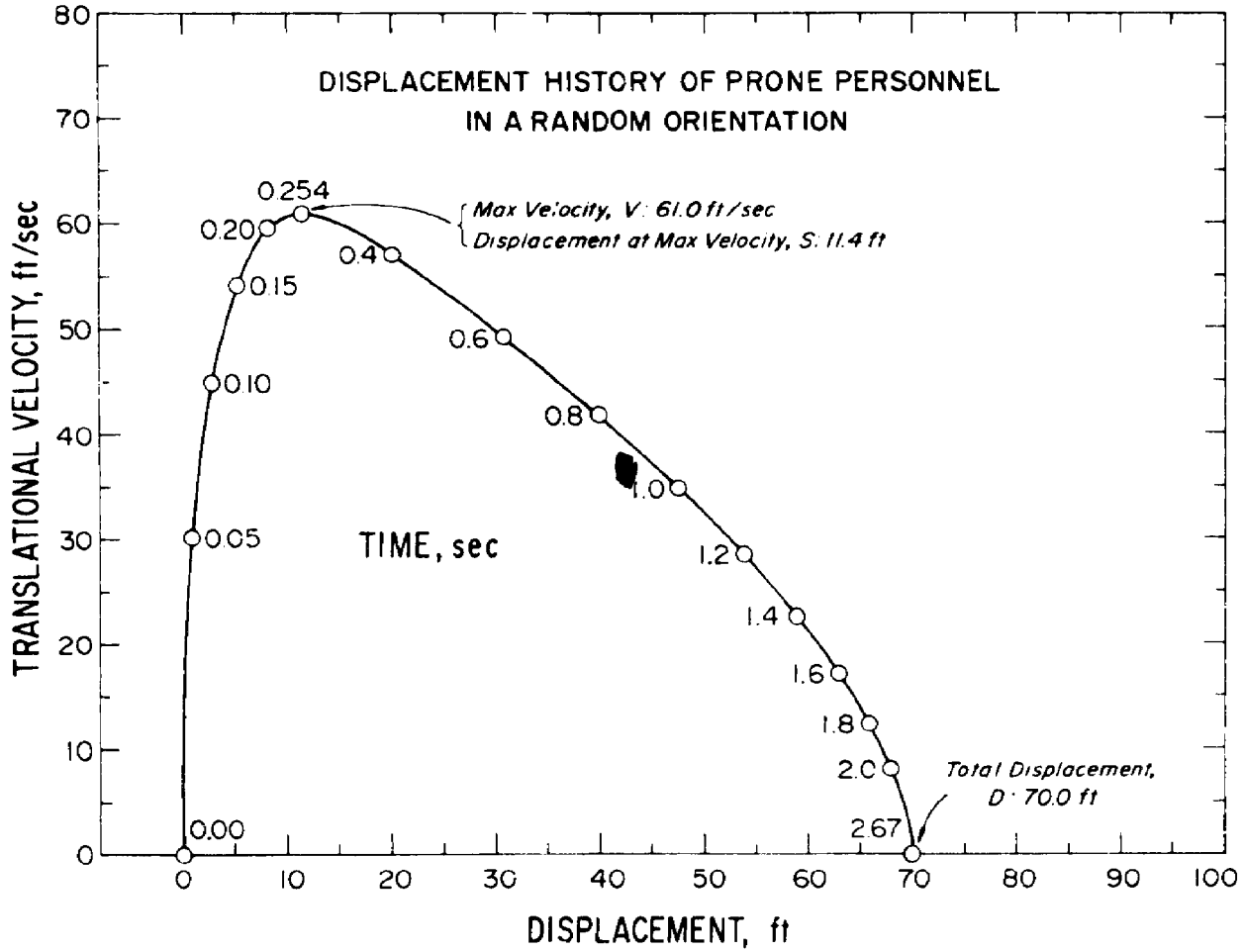

Figure A-1. Velocity-Displacement History of Prone Personnel in a Random Orientation Exposed to an Overpressure Level of 27.4 psi from a 10-KT Surface Burst. The data were taken from run number 10 in Table A-3.

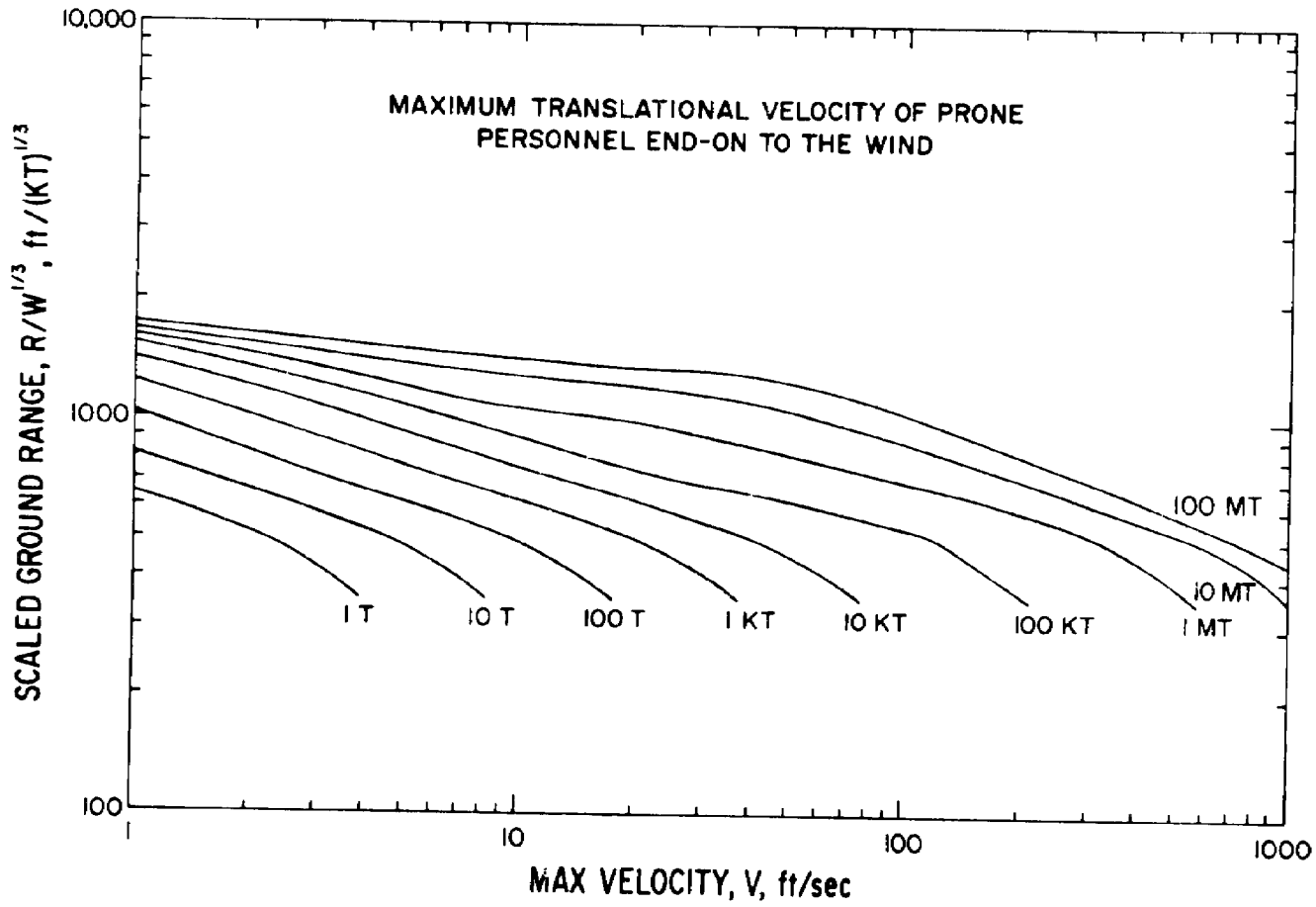

Figure A-2. Maximum Translational Velocity of Prone Personnel End-On to the Wind. Computed for a surface burst.

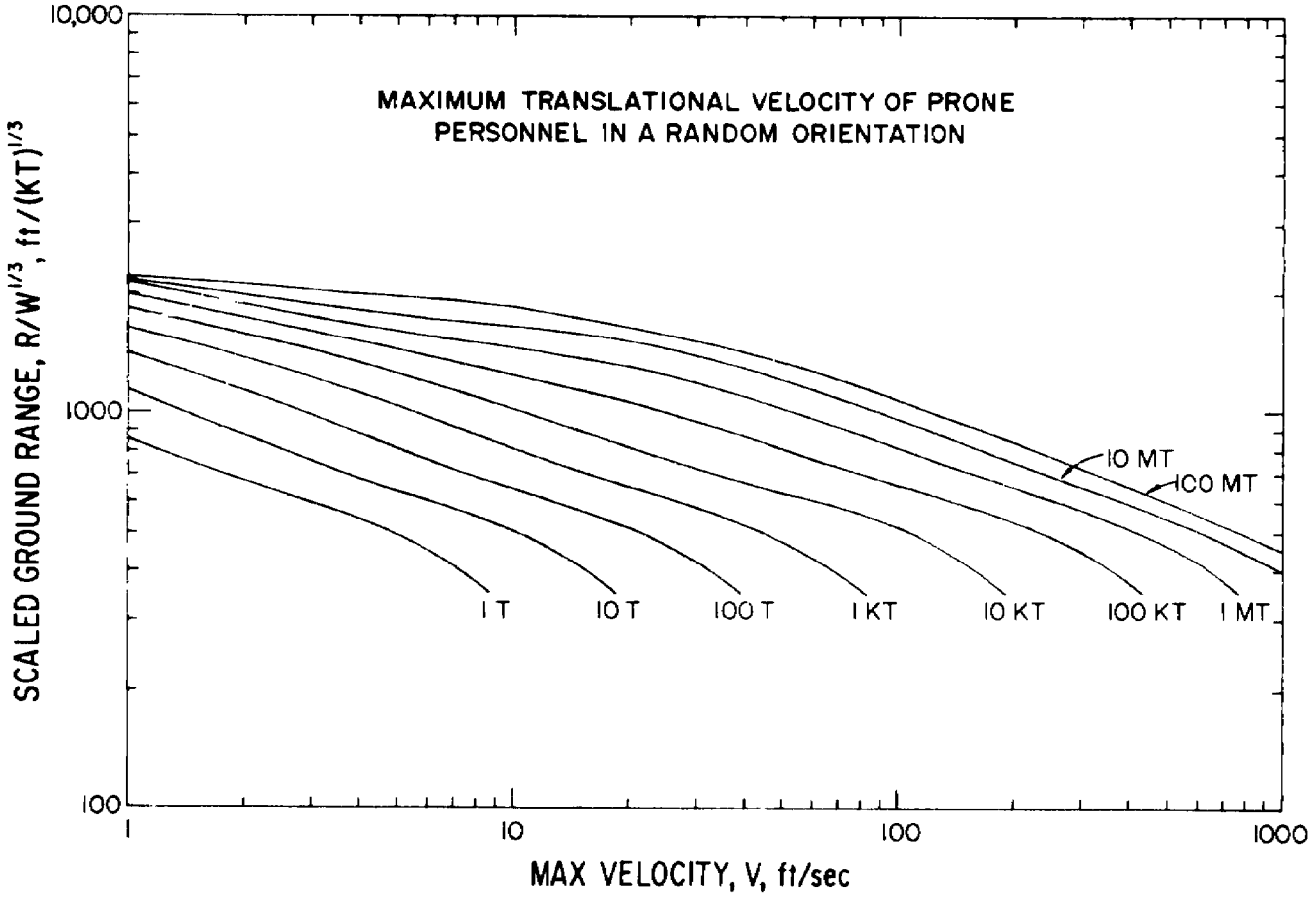

Figure A-3. Maximum Translational Velocity of Prone Personnel in a Random Orientation. Computed for a surface burst.

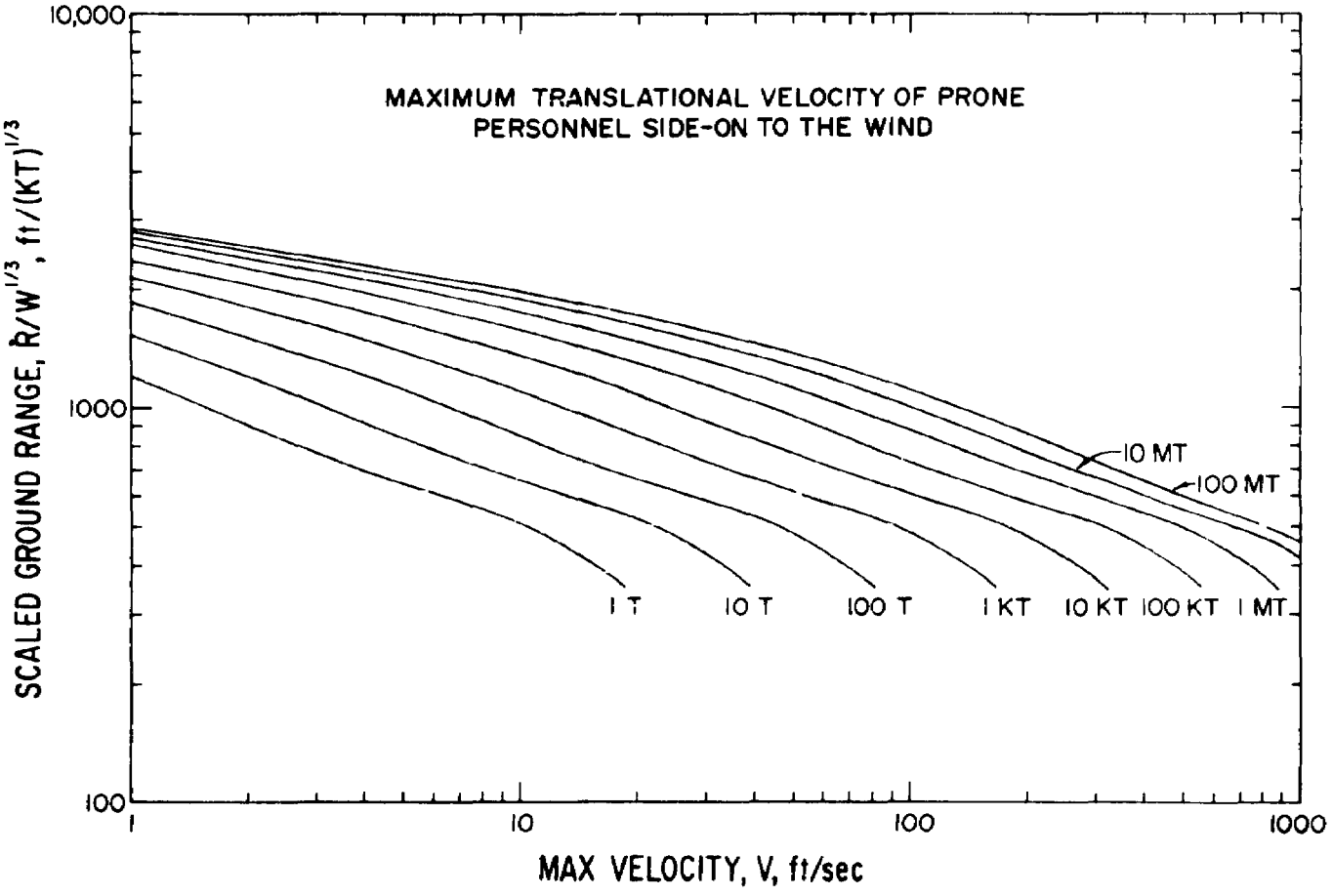

Figure A-4. Maximum Translational Velocity of Prone Personnel Side-On to the Wind. Computed for a surface burst.

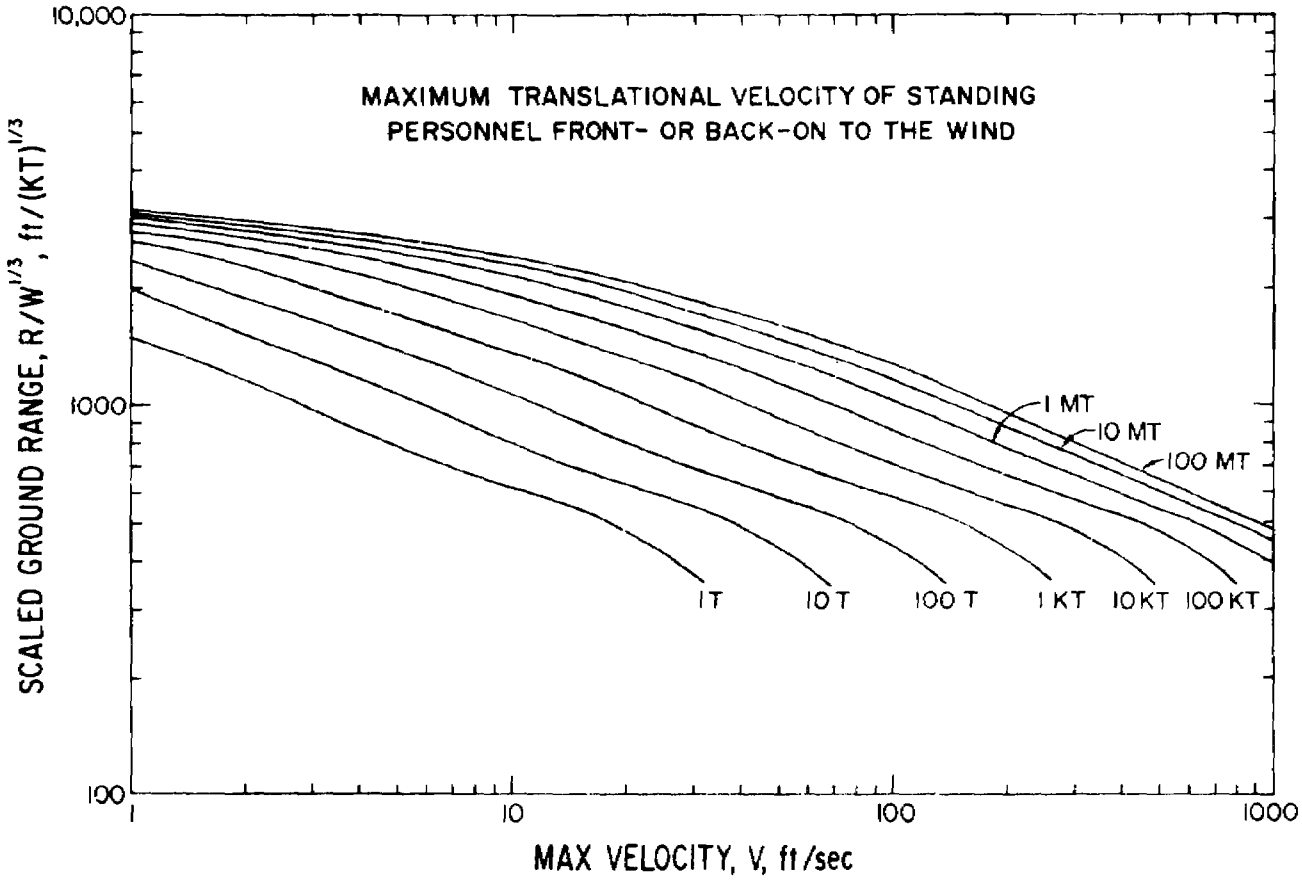

Figure A-5. Maximum Translational Velocity of Standing Personnel Front- or Back-On to the Wind. Computed for a surface burst.

TABLE A-1

BLAST-WAVE PARAMETERS USED TO CALCULATE DISPLACEMENT OF PERSONNEL

Run No.	$R/W^{1/3}$	$H/W^{1/3}$	P	$T_p/W^{1/3}$	$I_p/W^{1/3}$	Q	$T_q/W^{1/3}$	$I_q/W^{1/3}$
1	2600	0	1.98	.450	.411	.0934	.524	.0136
2	2200	0	2.56	.403	.469	.155	.477	.0199
3	1900	0	3.25	.365	.528	.249	.438	.0285
4	1600	0	4.34	.326	.600	.440	.402	.0437
5	1300	0	6.32	.284	.704	.913	.367	.0725
6	1100	0	8.32	.253	.800	1.51	.345	.106
7	950	0	11.0	.229	.880	2.50	.330	.147
8	850	0	13.7	.213	.940	3.71	.324	.184
9	700	0	20.0	.185	1.05	7.70	.314	.301
10	600	0	27.4	.165	1.15	14.0	.312	.474
11	500	0	40.5	.142	1.32	34.0	.314	.795
12	400	0	69.0	.115	1.64	107	.299	1.15
13	350	0	97.0	.100	1.99	143	.263	1.36
14	3000	948	3.14	.348	.371	.232	.421	.0173
15	2600	934	3.93	.328	.420	.362	.403	.0273
16	2200	913	5.19	.306	.485	.622	.387	.0432
17	1900	888	6.60	.290	.550	.958	.380	.0590
18	1600	850	8.62	.273	.635	1.44	.374	.0787
19	1300	795	11.9	.256	.767	2.32	.376	.114
20	1100	744	15.0	.242	.883	3.77	.377	.164
21	950	707	18.0	.228	.962	5.75	.374	.228
22	850	681	20.4	.215	.995	7.95	.367	.309
23	770	660	22.7	.204	1.01	10.7	.360	.401
24	700	636	25.4	.191	1.04	14.5	.351	.475
25	600	590	30.1	.167	1.12	20.4	.327	.537
26	500	529	39.5	.137	1.30	26.5	.299	.581
27	400	448	59.9	.104	1.70	38.6	.264	.644
28	950	320	15.0	.210	.893	4.31	.327	.303
29	850	320	17.5	.190	.935	6.72	.309	.279
30	770	311	20.3	.173	1.00	10.7	.295	.428
31	700	296	23.5	.158	1.09	19.6	.284	.600
32	600	276	30.9	.134	1.28	58.5	.265	.936
33	500	244	44.7	.109	1.58	127	.250	1.21
34	400	209	74.7	.0904	2.10	195	.237	1.49

H Height of Burst, ft
I_p Impulse of Positive Overpressure, psi·sec
I_q Impulse of Positive Dynamic Pressure, psi·sec
P Max Overpressure, psi
Q Max Dynamic Pressure, psi
R Ground Range, ft
T_p Duration of Positive Overpressure, sec
T_q Duration of Positive Dynamic Pressure, sec
W Nuclear Yield, KT

Note
Runs 1-13 correspond to a surface burst.
Runs 14-27 correspond to an upper optimum height-of-burst.
Runs 28-34 correspond to a lower optimum height-of-burst.

TABLE A-2

DISPLACEMENT OF PRONE PERSONNEL END-ON TO THE WIND

Run No.	1 T			10 T			100 T			1 KT			10 KT			100 KT			1 MT			10 MT			100 MT		
	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D
1	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.03	0.00	0.01	0.03	0.00	0.01	0.03	0.00	0.01	0.04	0.00	0.01	0.04	0.00	0.02
2	0.02	0.00	0.00	0.03	0.00	0.00	0.04	0.00	0.00	0.06	0.00	0.01	0.08	0.01	0.02	0.10	0.01	0.04	0.12	0.02	0.08	0.15	0.02	0.19	0.14	0.03	0.40
3	0.03	0.00	0.00	0.06	0.00	0.00	0.09	0.00	0.01	0.14	0.01	0.02	0.20	0.02	0.05	0.27	0.03	0.11	0.34	0.07	0.29	0.41	0.11	0.58	0.46	0.17	1.28
4	0.06	0.00	0.00	0.11	0.00	0.01	0.16	0.01	0.02	0.22	0.02	0.05	0.30	0.05	0.13	0.74	0.12	0.36	1.04	0.27	0.96	1.35	0.53	2.00	1.68	0.94	4.86
5	0.13	0.00	0.00	0.25	0.01	0.02	0.46	0.02	0.05	0.83	0.06	0.19	1.42	0.18	0.47	2.31	0.39	1.14	3.36	1.27	3.59	4.04	1.36	5.05	5.00	1.98	
6	0.21	0.00	0.01	0.42	0.01	0.03	0.81	0.03	0.10	1.50	0.12	0.33	2.70	0.38	1.04	4.64	1.15	3.19	7.58	3.36	13.41	12.0	4.57	22.5	20.1	6.98	38.8
7	0.32	0.00	0.02	0.65	0.01	0.05	1.28	0.05	0.18	2.46	0.19	0.60	4.58	0.66	1.95	8.22	2.15	6.14	24.8	20.3	47.1	77.9	40.7	122	101	48.1	128
8	0.43	0.00	0.02	0.87	0.02	0.08	1.74	0.07	0.27	3.43	0.28	0.91	6.53	0.92	2.97	12.1	3.16	9.16	41.2	29.2	76.2	111	108	143	178	244	327
9	0.76	0.01	0.05	1.57	0.05	0.19	3.21	0.12	0.43	6.47	0.48	2.14	12.7	1.80	7.10	26.1	7.12	30.2	89.8	57.0	207	207	180	700	307	190	1840
10	1.28	0.01	0.12	2.83	0.05	0.40	5.44	0.21	1.08	11.1	0.84	4.47	22.3	3.27	15.6	51.2	22.8	85.5	183	97.8	460	336	277	1300	457	563	2670
11	2.18	0.02	0.27	4.60	0.08	0.92	9.65	0.32	2.14	20.0	1.76	10.4	40.9	5.38	28.8	103	44.7	212	330	181	902	570	381	2300	766	758	4600
12	3.26	0.02	0.48	6.94	0.07	1.71	14.7	0.41	3.91	31.0	2.93	20.1	64.2	5.47	48.7	176	33.7	314	487	113	1180	800	377	2850	1220	766	6170
13	3.89	0.02	0.62	8.39	0.08	2.20	17.6	0.33	7.81	37.1	1.16	26.5	77.2	5.32	58.4	215	15.1	415	578	146	1430	1020	302	3250	1360	507	6780
14	5.02	0.00	0.80	8.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.60	0.31	0.00	0.13	0.01	0.02	0.16	0.02	0.05	0.24	0.03	0.12	0.30	0.05	0.26	0.15	0.09	0.58
15	0.04	0.00	0.00	0.07	0.00	0.00	0.11	0.00	0.01	0.18	0.01	0.02	0.29	0.02	0.09	0.43	0.05	0.15	0.80	0.11	0.37	0.79	0.22	0.85	0.98	0.39	1.90
16	0.07	0.00	0.00	0.13	0.00	0.01	0.23	0.01	0.02	0.41	0.03	0.06	0.69	0.06	0.17	1.09	0.17	0.47	1.64	0.41	1.23	2.31	0.82	2.96	3.16	1.84	10.0
17	0.13	0.00	0.00	0.21	0.00	0.01	0.38	0.01	0.04	0.70	0.04	0.11	1.23	0.13	0.35	2.05	0.32	1.00	3.25	0.47	2.72	4.47	2.38	8.17	10.2	4.47	32.9
18	0.18	0.00	0.01	0.31	0.01	0.02	0.56	0.02	0.06	1.12	0.07	0.20	2.02	0.22	0.64	3.52	0.68	1.91	5.80	1.08	5.35	8.34	3.25	12.2	16.2	5.55	42.1
19	0.25	0.00	0.01	0.50	0.01	0.04	0.94	0.03	0.12	1.80	0.12	0.37	3.55	0.45	1.36	6.40	1.40	4.04	11.1	4.05	18.4	16.1	5.92	24.8	30.1	14.2	108
20	0.38	0.00	0.02	0.78	0.01	0.07	1.57	0.06	0.23	3.09	0.21	0.76	5.94	0.76	2.41	11.0	2.90	8.26	18.4	7.23	37.0	27.0	10.4	48.4	54.9	27.2	147
21	0.56	0.01	0.05	1.15	0.02	0.12	2.34	0.09	0.40	4.88	0.33	1.35	9.13	1.22	4.47	17.4	4.44	14.2	29.2	11.8	66.4	42.9	16.9	86.4	86.4	44.1	265
22	0.78	0.01	0.08	1.62	0.03	0.19	3.31	0.13	0.67	6.87	0.50	2.25	13.2	1.88	7.47	27.7	7.17	23.1	46.8	19.1	109	68.8	27.5	154	138	72.0	474
23	1.04	0.01	0.09	2.16	0.04	0.30	4.44	0.18	1.01	9.00	0.70	3.48	17.9	2.67	11.6	45.8	12.9	38.5	74.8	30.6	175	110	44.2	248	221	116	762
24	1.25	0.02	0.12	2.62	0.05	0.40	5.43	0.21	1.37	11.1	0.82	4.63	22.3	3.18	15.5	60.1	22.1	82.6	140	52.9	336	211	76.4	477	425	200	1470
25	1.48	0.01	0.14	3.03	0.05	0.49	6.30	0.21	1.67	13.0	0.85	5.69	26.4	3.37	19.1	70.3	22.5	97.6	213	87.3	526	400	244	1520	764	505	3100
26	1.58	0.01	0.17	3.34	0.05	0.55	7.41	0.21	1.92	14.5	0.86	6.54	29.8	3.40	21.8	76.8	22.6	107	233	90.7	589	431	281	1620	823	541	3370
27	1.79	0.01	0.19	3.80	0.05	0.67	7.99	0.20	2.29	16.7	0.84	7.84	34.5	3.33	26.2	84.5	22.6	114	248	93.4	615	447	296	1725	736	541	3730
28	0.48	0.01	0.03	0.98	0.02	0.10	1.86	0.08	0.32	1.91	0.29	1.08	7.53	1.01	4.71	14.0	1.74	12.2	32.7	7.1	97.4	126	120	484	265	178	1060
29	0.69	0.01	0.05	1.43	0.03	0.15	2.91	0.11	0.50	3.85	0.44	1.87	11.47	1.65	7.28	22.3	7.72	25.4	49.3	52.6	151	199	179	838	283	172	1520
30	1.11	0.01	0.10	2.30	0.05	0.33	4.74	0.20	1.14	8.63	0.75	3.85	18.1	3.09	12.9	42.0	21.3	70.5	100	92.7	304	294	264	1140	409	535	2420
31	1.62	0.02	0.17	3.40	0.07	0.58	7.08	0.27	2.03	14.7	1.08	6.88	29.4	4.30	23.2	67.4	28.3	136	243	122	451	420	351	1740	587	662	3640
32	2.63	0.02	0.35	5.59	0.07	1.23	11.6	0.31	4.23	24.7	1.27	14.4	51.0	5.72	38.5	144	33.7	249	400	171	1010	721	475	2540	1110	762	5440
33	3.44	0.02	0.54	7.15	0.07	1.86	15.6	0.31	6.42	32.9	1.25	21.9	68.3	5.26	72.6	181	28.3	423	511	124	1360	951	362	2770	1360	736	6120
34	4.28	0.02	0.76	9.15	0.08	2.60	19.4	0.31	9.06	41.0	1.41	31.0	84.4	6.01	103	228	32.9	650	620	132	1410	1120	371	3090	1580	754	6660

V Max velocity ft/sec
S Displacement at Max Velocity ft
D Total Displacement ft

TABLE A-3

DISPLACEMENT OF PRONE PERSONNEL IN A RANDOM ORIENTATION

Run No	1 T			10 T			100 T			1 KT			10 KT			[illegible] KT			1 MT			10 MT			100 MT		
	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D
1	0 03	0 00	0 00	0 05	0 00	0 00	0 08	0 00	0 01	0 11	0 01	0 02	0 16	0 01	0 04	[illegible]	[illegible]	[illegible]	0 24	0 05	0 21	0 28	0 07	0 47	0 30	0 10	1 05
2	0 08	0 00	0 00	0 10	0 00	0 00	0 17	0 00	0 02	0 27	0 02	0 05	0 41	0 04	0 12	[illegible]	[illegible]	[illegible]	0 72	0 15	0 68	0 88	0 35	1 62	1 04	0 61	3 96
3	0 10	0 00	0 00	0 18	0 00	0 01	0 32	0 01	0 04	0 54	0 04	0 10	0 86	0 11	0 28	[illegible]	[illegible]	[illegible]	1 84	0 48	2 02	2 65	1 09	5 18	3 18	1 87	13 1
4	0 18	0 00	0 01	0 34	0 01	0 02	0 62	0 03	0 08	1 08	0 09	0 25	1 86	0 24	0 75	[illegible]	[illegible]	[illegible]	3 47	1 21	3 93	5 14	3 15	9 36	6 18	3 84	23 0
5	0 34	0 01	0 02	0 68	0 02	0 06	1 16	0 07	0 21	2 17	0 21	0 67	4 48	0 77	2 35	[illegible]	[illegible]	[illegible]	7 21	3 14	9 37	10 6	6 40	19 9	12 1	8 7 9	39 1
6	0 54	0 01	0 03	1 09	0 03	0 12	2 11	0 15	0 47	3 17	0 41	1 42	7 88	1 48	4 82	17 7	2 95	10 1	10 6	5 42	20 1	20 1	11 7	32 1	18 1	11 7	32 1
7	0 79	0 01	0 04	1 62	0 04	0 21	3 26	0 26	0 70	4 81	0 73	2 33	12 6	2 48	8 13	[illegible]	12 2	36 3	15 2	11 1	31	30 2	19 6	53	29 7	19 6	53
8	1 02	0 01	0 09	2 11	0 05	0 30	4 30	0 39	1 02	6 61	0 78	3 43	17 4	3 38	12 3	47 1	15 6	54 2	20 7	15 2	185	144	29 3	478	108	27 0	1080
9	1 27	0 02	0 20	3 69	0 08	0 69	7 62	0 54	2 04	15 6	1 08	7 93	33 9	6 89	30 4	82 2	28 9	127	139	45 9	386	248	210	880	330	412	1800
10	2 89	0 01	0 32	6 08	0 14	1 48	12 6	0 97	5 03	26 2	2 28	17 2	82 0	11 4	70 0	111	43 9	267	267	131	719	382	310	1550	480	585	2880
11	4 92	0 05	0 48	10 4	0 19	3 18	21 9	0 83	11 5	44 1	3 60	30 7	130	16 2	161	246	61 6	542	486	182	1260	634	418	2670	788	782	4870
12	7 29	0 04	1 00	15 5	0 33	6 22	32 8	0 78	21 2	64 2	5 05	41 0	160	14 8	286	368	57 6	788	671	177	1640	999	418	3280	1280	792	6480
13	9 68	0 05	1 38	19 3	0 42	8 24	38 1	0 85	28 1	82 7	6 24	54 5	182	16 4	326	424	62 9	999	781	191	1910	1140	456	3700	1450	823	7310
14	0 08	0 00	0 00	0 11	0 00	0 00	0 19	0 01	0 02	0 32	0 02	0 05	0 53	0 03	0 13	1 81	0 12	0 34	1 19	0 28	0 85	1 61	0 60	2 19	2 64	0 46	11 2
15	0 18	0 00	0 00	0 29	0 00	0 01	0 36	0 03	0 04	0 64	0 04	0 11	1 08	0 12	0 33	1 77	0 34	0 92	2 72	0 89	2 82	5 44	2 87	12 9	11 2	17 0	47 8
16	0 19	0 00	0 01	0 37	0 01	0 05	0 70	0 03	0 08	1 29	0 09	0 27	2 29	0 30	0 84	5 02	0 93	2 57	7 30	2 05	11 08	19 0	17 3	45 1	31 9	41 4	130
17	0 28	0 00	0 01	0 55	0 01	0 04	1 08	0 04	0 15	2 05	0 16	0 48	3 77	0 53	1 55	8 80	1 84	5 27	16 7	10 3	24 7	34 4	30 6	86 7	53 9	71 2	232
18	0 60	0 00	0 02	0 80	0 02	0 07	1 59	0 07	0 25	3 08	0 24	0 78	5 82	0 85	2 67	11 2	3 33	10 3	28 7	16 5	45 1	54 4	47 9	140	82 3	109	388
19	0 81	0 01	0 03	1 25	0 03	0 14	2 51	0 11	0 42	4 93	0 41	1 56	9 84	1 52	5 24	21 7	8 01	22 3	50 2	28 1	88 0	88 6	78 0	256	128	168	610
20	0 92	0 01	0 04	1 90	0 04	0 25	3 87	0 17	0 66	7 77	0 64	2 89	15 5	2 63	10 1	42 7	12 8	44 3	80 9	43 0	158	136	117	421	191	245	945
21	1 32	0 01	0 11	2 74	0 06	0 44	5 54	0 25	1 49	11 4	0 97	5 02	23 7	4 49	14 4	78 2	19 1	79 2	119	80 5	261	193	162	641	264	329	1380
22	1 82	0 02	0 21	3 80	0 09	0 72	7 65	0 36	2 46	15 0	1 34	6 71	35 2	7 20	32 2	85 1	27 4	133	164	88 9	405	256	218	911	380	427	1870
23	2 39	0 03	0 32	5 05	0 12	1 11	10 6	0 48	3 77	21 3	2 00	12 8	48 1	9 76	51 7	115	37 6	204	214	113	577	324	276	1280	422	528	2440
24	2 87	0 01	0 42	6 14	0 15	1 46	12 6	0 55	4 98	26 1	2 31	17 0	60 5	11 1	68 7	139	42 7	263	258	131	719	390	310	1580	505	593	2900
25	3 29	0 03	0 52	6 94	0 15	1 77	14 5	0 55	6 09	30 2	2 34	20 8	69 7	11 1	82 4	162	43 2	311	303	133	828	458	321	1810	595	620	3330
26	3 59	0 03	0 59	7 41	0 13	2 04	16 0	0 54	6 88	33 3	2 29	23 7	76 1	10 8	92 1	178	42 3	340	334	132	898	507	318	1930	658	616	3630
27	4 04	0 03	0 70	8 58	0 12	2 43	18 1	0 51	8 31	37 7	2 16	28 2	84 9	10 1	106	199	38 5	392	377	124	979	575	301	2040	756	705	4310
28	1 15	0 01	0 10	2 17	0 06	0 36	4 85	0 25	1 21	9 75	0 89	4 08	30 0	3 99	14 9	49 6	17 6	85 0	101	58 5	217	183	149	547	222	239	1190
29	1 64	0 02	0 18	3 04	0 08	0 60	6 97	0 32	2 05	14 2	1 28	6 85	30 6	6 45	26 8	74 8	25 2	112	144	81 1	347	229	203	815	308	364	1680
30	2 56	0 03	0 36	5 37	0 13	1 25	11 1	0 56	4 18	22 9	2 25	16 3	53 5	10 9	56 6	125	42 0	228	224	127	625	335	295	1360	470	556	2890
31	3 70	0 04	0 53	7 79	0 17	2 17	16 3	0 70	7 38	34 0	3 04	25 4	80 8	14 2	105	182	53 8	381	327	160	959	481	389	2030	615	691	3870
32	5 91	0 03	1 30	12 4	0 34	4 48	26 5	0 76	15 3	55 4	3 83	52 1	131	14 9	202	288	57 4	659	547	175	1470	821	418	2930	1060	812	5680
33	7 69	0 04	1 96	16 4	0 47	6 78	34 7	0 73	23 1	73 1	5 15	77 4	188	13 9	285	388	55 7	836	720	167	1820	1160	476	3230	1440	792	8600
34	9 55	0 04	2 78	20 4	0 19	9 58	43 1	0 86	32 8	90 4	3 49	110	208	15 1	401	471	57 4	1110	881	174	1900	1240	409	3570	1670	776	7160

V Max Velocity, ft/sec
S Displacement at Max Velocity, ft
D Total Displacement, ft

TABLE A-4

DISPLACEMENT OF PRONE PERSONNEL SIDE-ON TO THE WIND

Run No.	1 T			10 T			100 T			1 KT			10 KT			100 KT			1 MT			10 MT			100 MT		
	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D
1	0 [illegible]	0 00	0 00	0 16	0 00	0 01	0 28	0 01	0 03	0 45	0 04	0 09	0 68	0 09	0 25	0 96	0 22	0 [illegible]	1 28	0 44	1 47	1 59	0 81	3 25	1 66	1 33	7 37
2	0 16	0 00	0 01	0 30	0 01	0 02	0 53	0 03	0 07	0 91	0 08	0 22	1 46	0 24	0 62	2 27	0 62	1 [illegible]	3 25	1 32	4 12	4 28	2 49	9 [illegible]	5 27	5 21	21 8
3	0 26	0 00	0 01	0 50	0 01	0 04	0 93	0 05	0 14	1 67	0 17	0 45	3 05	0 51	1 35	4 [illegible]	1 45	1 79	6 88	3 56	9 85	9 55	7 40	23 [illegible]	12 2	16 8	54 4
4	0 44	0 01	0 03	0 87	0 03	0 08	1 67	0 10	0 31	3 04	0 35	0 89	5 48	1 11	3 04	9 18	3 26	8 48	14 3	8 39	23 8	20 5	18 8	57 8	27 1	37 1	133
5	0 82	0 01	0 07	1 65	0 05	0 22	3 27	0 20	0 75	6 28	0 72	2 41	11 6	2 44	7 54	20 2	7 54	22 2	32 4	20 4	59 8	47 4	47 2	146	63 0	92 8	330
6	1 25	0 02	0 12	2 56	0 08	0 42	5 16	0 31	1 41	10 1	1 16	4 59	18 9	4 01	14 2	39 2	12 7	41 0	55 5	34 4	108	78.0	79 5	206	103	156	586
7	1 79	0 03	0 21	3 71	0 13	0 72	7 54	0 43	2 42	14 8	1 68	7 88	28 2	5 83	21 2	56 1	18 4	68 3	81 1	50 1	173	118	115	398	155	222	853
8	2 29	0 03	0 30	4 77	0 13	1 06	9 76	0 53	3 50	19 4	2 21	11 4	37 1	7 16	14 8	69 0	22 8	98 0	108	62 8	240	157	144	530	205	276	1100
9	3 48	0 05	0 44	6 14	0 21	2 36	12 6	0 84	7 90	23 7	3 26	15 4	44 5	11 8	26 0	115	28 8	203	134	98 7	272	183	222	958	249	420	1880
10	8 30	0 08	1 48	11.	[illegible]	5 03	27 3	1 34	16 8	54 8	5 16	33 2	104	18 2	154	183	58 7	767	288	148	835	400	324	1650	500	594	2830
11	10.8	0 11	3 36	22 4	0 48	11 4	48 4	3 85	38 0	93 4	7 15	114	178	24 9	328	270	76 7	731	482	200	1420	880	436	2760	832	791	4990
12	15 8	0 20	8 [illegible]	33 1	0 41	21 1	69 1	1 68	69 9	140	6 50	216	270	23 3	560	478	71 0	1070	754	188	1860	1050	636	3470	1310	795	6860
13	18 8	0 11	8 [illegible]	38 4	0 43	27 8	88 1	1 85	82 2	186	7 17	284	318	25 5	723	560	79 6	1310	873	211	2310	1200	680	3900	1480	833	7390
14	0 15	0 00	0 01	0 29	0 01	0 02	0 55	0 02	0 08	1 00	0 07	0 20	1 72	0 22	0 59	2 45	0 83	1 88	4 42	1 58	4 48	6 42	3 63	11 1	8 88	7 42	26 5
15	0 26	0 00	0 01	0 52	0 01	0 04	1 00	0 05	0 14	1 85	0 16	0 45	3 31	0 50	1 40	5 82	1 49	4 12	8 98	3 01	11 2	13 3	9 08	28 4	18 2	20 0	84 4
16	0 48	0 01	0 02	0 92	0 02	0 09	1 80	0 09	0 27	3 43	0 32	1 02	6 31	1 08	3 20	11 0	3 20	9 12	16 0	5 13	20 1	27 0	22.1	86 4	37 2	46 0	155
17	0 68	0 01	0 05	1 34	0 03	0 16	2 67	0 13	0 53	5 18	0 48	1 74	9 72	1 68	5 51	17 2	5 38	16 4	28 8	15 1	45 4	43 8	36 9	114	58 9	77 0	282
18	0 92	0 01	0 08	1 88	0 05	0 26	3 80	0 19	0 87	7 48	0 70	2 35	14 2	2 47	9 01	25 8	7.97	26 7	42 7	22 8	72 8	64 8	55 7	179	88 9	115	404
19	1 39	0 02	0 14	2 87	0 07	0 48	5 84	0 29	1 62	11 8	1 11	3 31	22 2	3 65	16 8	40 2	12 8	48 1	66 9	38 2	126	88 6	78 0	254	136	177	652
20	2 06	0 03	0 26	4 26	0 11	0 88	8 38	0 43	2 85	17 6	1 67	0 83	33 8	5 80	29 7	61.1	19 2	84 9	101	3 9	212	150	128	475	199	253	994
21	2 92	0 04	0 44	6 10	0 15	1 51	12 6	0 62	5 06	25 2	2 35	15 4	49 6	8 53	48 9	87 4	27 2	137	140	75 1	333	209	174	788	273	338	1420
22	4 00	0 05	0 72	8 39	0 22	2 48	17 3	0 88	8 26	34 7	3 38	26 6	68 5	12 0	79 5	116	37 8	211	180	102	494	272	230	1010	349	436	1930
23	5 24	0 07	1 11	11 0	0 29	3 79	22 7	1 17	12 8	45 5	4 48	40 2	88.7	15 8	116	153	50 1	303	242	130	881	342	289	1370	431	537	2510
24	6 26	0 08	1 48	13 2	0 32	4 99	27 2	1 31	16 8	54 7	5 02	52 8	108	17 7	153	184	55 0	384	292	148	658	410	324	1680	515	603	2990
25	7 13	0 08	1 78	15 0	0 34	6 09	31 2	1 30	20 3	62 9	5 01	64 5	121	17 8	186	214	55 8	455	342	156	987	482	336	1930	608	610	3430
26	7 77	0 07	2 03	16 4	0 31	6 85	34 2	1 28	23 2	68 1	4 88	73 8	135	17 4	212	237	55 0	509	387	148	1040	534	333	2090	672	627	3740
27	8 70	0 07	2 42	18 4	0 [illegible]	8 28	38 4	1 17	27 8	78 0	4 36	86 0	151	16 4	232	269	51 8	588	430	140	1440	607	315	2180	773	612	4120
28	2 56	0 03	0 16	5 33	0 14	1 53	15 9	0 58	6 14	21 8	2 23	13 6	41 8	7 97	41 0	74.5	25.4	113	121	89.5	278	176	180	804	229	307	1240
29	3 58	0 05	0 31	7 49	0 20	2 08	25 4	0 78	8 95	30 4	3 08	22 4	58 2	10 9	87 4	105	34 6	183	170	93 8	428	244	212	888	314	402	1740
30	5 60	0 08	1 23	11 8	0 32	4 20	24 2	1 28	14 0	48 5	4 98	44 4	91 6	17 5	150	160	54 0	331	262	142	729	351	309	1650	450	564	2660
31	8 02	0 10	2 16	16 9	0 42	7 36	34 9	1 65	24 4	69 8	6 27	77 2	133	22 0	221	232	67 6	552	383	176	1090	503	383	2156	636	700	3710
32	12 7	0 10	4 45	26 9	0 62	15 2	56 0	2 70	50 6	113	5 56	158	218	33 2	430	366	72 6	897	632	194	1600	881	455	2100	1080	827	5020
33	16 5	0 09	6 73	35 0	0 39	23 0	73 0	1 59	76 1	148	6 14	236	287	21 9	612	531	69 0	1120	818	188	1820	1160	423	3440	1480	802	6310
34	20 4	0 10	9 [illegible]	43 3	0 42	32 4	90 2	1 73	107	183	6 66	330	351	23.5	852	618	73 0	1450	974	194	2110	1360	485	3790	1710	788	7380

V Max Velocity ft/sec
S Displacement at Max Velocity ft
D Total Displacement ft

TABLE A-5

DISPLACEMENT OF STANDING PERSONNEL FRONT- OR BACK-ON TO THE WIND

Run No	1 T			10 T			100 T			1 KT			10 KT			100 KT			1 MT			10 MT			100 MT		
	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D	V	S	D
1	0.19	0.00	0.01	0.38	0.01	0.03	0.63	0.04	0.10	1.76	0.11	0.28	3.70	0.30	0.80	7.58	0.77	2.12	9.59	1.89	5.12	4.65	3.38	11.9	5.67	8.04	28.8
2	0.40	0.01	0.03	0.78	0.03	0.10	1.26	0.08	0.23	2.26	0.25	0.71	3.88	0.80	2.18	6.26	2.23	6.13	9.29	5.43	15.6	12.7	11.5	36.9	15.9	21.6	83.1
3	0.61	0.01	0.05	1.22	0.04	0.16	1.88	0.12	0.37	3.48	0.40	1.18	6.06	1.30	3.56	9.92	3.68	10.1	15.0	9.17	26.1	20.7	19.6	61.9	26.1	37.1	139
4	0.83	0.01	0.07	1.66	0.06	0.23	2.53	0.22	0.37	4.89	0.76	2.44	10.9	2.44	7.49	18.2	7.19	21.0	27.7	17.9	54.1	38.5	38.0	127	49.0	69.8	280
5	1.49	0.02	0.16	3.04	0.10	0.55	5.05	0.40	1.42	11.7	1.39	5.81	21.4	5.02	17.4	36.1	14.2	47.4	55.5	35.9	117	76.9	77.2	265	98.8	141	568
6	2.25	0.04	0.30	4.63	0.15	1.02	9.32	0.38	3.39	18.1	2.20	10.7	33.3	7.62	31.4	56.1	21.9	82.3	85.4	54.8	182	117	116	418	145	202	886
7	3.18	0.05	0.51	6.80	0.21	1.74	13.4	0.80	5.75	26.1	3.03	18.0	48.0	10.5	51.8	80.9	29.7	131	122	69.5	292	166	166	583	205	255	1200
8	4.05	0.06	0.74	8.62	0.25	2.52	17.3	0.99	8.29	33.8	3.69	26.8	62.1	12.2	73.3	105	36.2	182	159	89.1	395	216	183	788	265	319	1500
9	6.81	0.09	1.68	14.2	0.39	5.86	28.0	1.54	16.3	56.6	5.69	58.5	104	18.6	154	174	50.9	351	258	130	707	344	260	1330	415	448	2340
10	11.0	0.15	1.57	22.9	0.63	12.0	46.6	2.38	38.8	90.7	8.68	115	164	28.8	294	268	75.4	602	388	183	1120	500	358	2100	589	607	3520
11	18.4	0.20	3.12	38.4	0.81	27.2	78.2	3.18	66.7	152	11.5	248	274	38.4	559	442	102	952	630	236	1680	798	459	3180	927	768	5700
12	26.8	0.17	14.9	56.5	0.72	49.9	116	2.83	154	228	10.3	432	416	33.8	830	679	95.6	1180	981	226	1950	1260	432	3880	1480	741	7060
13	32.0	0.19	19.7	67.2	0.78	66.0	138	1.09	208	268	11.2	562	467	36.6	1040	787	102	1390	1120	238	2180	1420	460	4960	1650	759	7690
14	0.19	0.00	0.01	0.38	0.01	0.05	1.11	0.05	0.16	2.07	0.18	0.53	3.70	0.37	1.42	8.24	1.86	4.87	9.86	4.37	12.5	14.4	10.6	30.8	19.3	20.1	71.0
15	0.50	0.01	0.03	1.00	0.03	0.11	1.95	0.10	0.36	3.69	0.36	1.15	8.69	1.19	3.56	13.4	3.57	10.3	18.1	9.38	27.4	36.3	21.3	66.6	35.0	42.0	182
16	0.84	0.01	0.07	1.71	0.05	0.23	3.40	0.18	0.77	6.55	0.69	2.50	12.1	2.12	7.06	20.9	7.03	21.9	33.2	18.5	57.1	67.8	41.6	135	62.8	79.8	299
17	1.20	0.02	0.11	2.45	0.07	0.38	4.93	0.27	1.30	9.61	1.09	4.19	17.9	3.43	12.7	31.1	10.6	35.6	49.3	27.5	90.3	71.1	61.2	208	92.5	118	450
18	1.65	0.02	0.19	3.41	0.10	0.63	6.68	0.37	2.10	13.5	1.58	6.74	25.3	4.77	20.2	44.0	14.5	55.2	69.8	37.9	135	99.6	83.2	299	128	155	629
19	2.67	0.04	0.34	5.32	0.14	1.17	10.4	0.57	3.47	20.5	2.31	12.3	38.2	7.17	35.9	66.0	21.8	94.3	103	54.5	218	144	116	455	182	212	921
20	3.83	0.05	0.62	7.56	0.21	2.12	15.4	0.79	7.01	30.3	2.98	21.8	56.9	9.98	62.6	97.8	30.6	160	151	76.2	355	208	166	700	260	286	1360
21	5.13	0.07	1.07	10.7	0.28	3.63	21.9	1.12	11.9	43.1	4.19	36.9	80.0	13.9	103	136	40.4	248	206	102	529	280	210	1010	343	368	1860
22	7.08	0.10	1.80	14.8	0.40	6.05	30.1	1.57	19.7	58.0	5.86	59.7	109	18.6	160	180	54.6	362	267	132	739	354	272	1390	425	470	2450
23	8.36	0.14	2.80	19.5	0.56	9.37	39.6	2.19	30.2	77.1	7.93	90.0	140	25.5	232	229	75.4	493	333	168	966	433	331	1820	534	583	3110
24	10.8	0.14	3.56	23.4	0.56	11.9	46.4	2.29	38.4	90.8	8.45	114	160	26.8	289	273	73.9	589	398	174	1120	514	356	2140	608	588	3590
25	11.8	0.13	3.88	25.9	0.57	14.5	50.6	2.07	42.7	99.7	7.59	130	190	28.1	344	302	70.5	632	446	171	1180	600	371	2340	714	624	3840
26	13.5	0.13	4.92	26.2	0.55	16.8	57.8	2.19	53.4	114	8.08	159	209	26.5	368	348	75.3	723	484	149	1550	628	283	2400	781	621	4360
27	15.0	0.11	5.46	31.6	0.50	19.7	61.0	1.74	57.7	118	7.23	188	235	23.7	453	374	63.0	765	572	187	1830	744	330	2830	868	545	4490
28	4.80	0.07	0.88	9.58	0.27	2.98	19.1	1.08	9.78	37.5	4.07	30.4	88.3	13.8	85.7	117	38.7	218	177	97.4	451	238	200	847	285	348	1860
29	6.27	0.09	1.48	13.1	0.36	4.88	26.7	1.42	16.3	52.3	5.46	50.0	96.2	17.8	137	161	50.9	320	240	123	657	318	253	1430	388	446	2210
30	8.76	0.16	2.91	20.3	0.54	10.0	41.4	2.23	32.4	80.3	8.47	98.9	145	27.2	253	237	73.3	540	341	175	1030	440	345	1900	526	579	3240
31	13.8	0.18	5.22	29.6	0.72	17.5	59.1	2.64	56.2	118	10.3	185	206	31.3	409	336	88.2	788	480	206	1410	616	414	2650	736	722	4480
32	22.0	0.18	10.8	46.2	0.74	36.3	94.2	2.88	115	185	10.5	330	335	33.5	696	553	85.7	1070	807	228	1770	1040	444	3270	1258	796	6810
33	26.4	0.16	16.3	59.8	0.67	54.7	123	2.71	174	243	9.58	483	448	32.8	924	749	96.5	1280	1100	235	2070	1440	491	4280	1730	834	7740
34	35.1	0.18	22.9	73.6	0.76	76.4	151	2.64	240	295	9.81	638	538	31.9	1110	875	90.8	1380	1260	199	2060	1630	417	4600	1940	684	7900

V Max Velocity, ft/sec
S Displacement at Max Velocity, ft
D Total Displacement, ft

TABLE A-6

BIOLOGICAL CRITERIA

Probability of Serious Injury, Percent	Impact Velocity, ft/sec, for Normal Incidence Against a Nonyielding, Flat Surface	Maximum Velocity, ft/sec, for Decelerative Tumbling Over Open Terrain
1	6.5 (4.5-8.2)	28.8 (12.7-37.8)
2.5	7.5 (5.4-9.2)	32.9 (16.7-41.4)
5	8.4 (6.3-10.1)	36.8 (21.1-44.8)
50	15.4 (13.5-17.3)	66.4 (58.2-82.9)
95	28.4 (24.8-34.7)	120 (91.8-268)
	$y = -2.384+6.211 \log x$	$y = -6.705+6.423 \log x$

y is the probability of injury in probit units.
x is the velocity.
95% confidence limits for the velocities are given in parentheses.

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